Hybrid material designs by the example of additive manufacturing for novel customized stab protective clothing

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Abstract

The almost unlimited potential that is and will be provided by additive manufacturing processes is an important current research topic. In terms of textile and ready-made technologies, composite structures can be created through continuously fiber-reinforced additive manufacturing and joined on planar textile surfaces. Based on the combination of flexible and rigid materials, innovative multi-material structures can be produced.
The developed concept employs the use of hybrid materials for protective clothing. This research focusses on stab-proof vests for the human torso. The benefits of protective clothing can only come into effect when worn so the willingness to wear is an essential factor for personal protection. Typically, the protective function is enhanced by increasing weight, which in turn leads to a decrease in wear comfort and willingness to wear this garment. This novel solution approach aims for the realization of lightweight protective clothing based on innovative technologies and hybrid materials.

The combination of continuous aramid fiber-reinforced structures for protection elements and textile materials is aimed at uniting flexibility, mobility, and protection to extend the limitations of state-of-the-art protective clothing. Fused Deposition Modeling (FDM) is suitable for the integration of continuous fibers into the manufacturing process. Requirement-adapted manufacturing based on the Continuous Filament Fabrication (CFF) process is enabled by adjustable fiber angles. By high-performance fibers such as aramid, thin and lightweight protection elements can be produced with freedom of design.

The design approach employs biomimicry with respect to several organisms (e.g. fish, snakes, armadillos) that have successfully overcome the conflict between maximum protection against mechanical influences and mobility. There are rarely any specifications in terms of material selection as well as optimum thickness, size, shape, and arrangement of protective elements. Based on a geometric curvature analysis investigating the human torso and revealing the suitable arrangement of protective elements, their shape and size are selected. The combination with 3D body scans additionally allows for individual design modifications.
Fundamental questions involving adhesion and the calculation of characteristic values must

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be addressed. Additively manufactured elements reinforced with aramid fibers are experimentally characterized in terms of stab protection for different layered structures, i.e. various fiber volume contents and fiber deposition angles, to determine the reinforcing benefit provided. 3D geometric models generated by CAD allow for the combined manufacturing of protective elements using FDM and CFF procedures directly on textile fabrics. Future research will be aimed at producing customized stab-proof vests based on a continuous CAE process chain.

Keywords: Additive manufacturing, protective clothing, composites, textiles, CAD